GEOLOGY.

The parish of Tynemouth and chapelry of Earsdon include some of the most interesting geological features to be found in the whole of Northumberland. In the first place, the district contains the only outcrops of Permian strata north of the Tyne, while the Coal-measures include most of the important seams worked in the county. In some cases, the shales associated with these beds enclose magnificent specimens of fish and reptiles, a splendid suit of which, obtained by local collectors, is exhibited in the Hancock Museum at Newcastle-upon-Tyne; while the sandstones show features of some interest. The glacial deposits again are finely exposed in a continuous section on the north bank of the Tyne, and afford information of importance concerning the origin of these deposits in Northumberland.

Permian.—These rocks occur in the form of outliers from the main mass of the Permian beds which bulk so large along the coastline south of the Tyne. They crop out at Tynemouth, Whitley and Cullercoats, and also at Hartley, where, however, only the lowest beds are seen capping the cliff near the old lime-kiln. They occur again at Clousden Hill, near Killingworth, outside this parish. They include representatives of the lower yellow sands, marl-slate and lower 'compact' and middle 'cellular' limestones of Sedgwick and Howse. The most southerly of these outliers, namely, that under Tynemouth castle, forms the northern limit of the main mass of the Permian in Durham. The block of the same strata at Whitley, Cullercoats and Hartley represents a further extension of these beds to the north, let down and preserved by the Ninety-fathom dyke. How much farther north in Northumberland the Permian beds were originally deposited it is now impossible to say, but the presence of the Middle Limestone at Whitley shows that the whole series must have once extended much farther north, since that bed was by no means a shore deposit. In this connection, it is interesting to note the occurrence of a large boulder of fossiliferous Magnesian Limestone, recorded by Kirkby in 1865, which was washed out of the till at the south end of Whitley sands, about a mile north of the present outcrop of these beds. The Lower and Middle Limestones were formerly well exposed at Whitley quarries, where the lower bed was noted for its fossils, for Kirkby, writing of these beds in 1865, specially alludes to this locality as the 'ultima Thule' of the Magnesian Limestone and its fossils. The quarry was afterwards drowned out by water, and the fossiliferous bed, which lay towards the bottom, rendered inaccessible.

In the cliff at Tynemouth the lower bed was broken up and formed into a conglomerate, previous to the deposition of the upper 'concretionary' ('cellular') bed upon it. From this bed Kirkby quotes as many as twenty species on the authority of Professor King. In Northumberland, as in many places in Durham and Germany, the Lower Limestone rests on and passes into a shaly marl-slate, which thins out and disappears in the south of Durham. It seldom reaches a yard in thickness and its chief fossil contents are fishes, reptiles and plant remains. This bed was formerly exposed between tide-marks on the south side of Cullercoats bay, where it occurred as a sandy bituminous shale. It has here yielded many fine specimens of ganoid fishes, *Platysomus striatus*, *Pygopterus mandibulatus* and *Acentrophorus glaphyrus*, together with several species of *Palaeoniscus*, of which *P. Freieslebeni* (Blainv) is by far the commonest. From Cullercoats also have been recorded specimens of the shark, *Woodnika striatula* (Münster), and the ray, *Janassa bituminosa* (Schloth). At the present day (1905) the bed is practically worked out, though the writer succeeded in obtaining a specimen of *Palaeoniscus* at low spring tide in the summer of 1904. Plant remains are very poorly preserved in this exposure, but specimens of *Ullmannia selaginoides* occur in the slate under Tynemouth castle.

The yellow sands below form an incoherent unfossiliferous deposit. Local in character and of variable thickness, they are often false-bedded and the grains of quartz are frequently much rounded. These characters point to deposition under shallow water or even shore conditions, and they may possibly represent an æolian deposit of the nature of sand dunes. The sands rest unconformably upon the denuded surface of the Coal-measures, which under Tynemouth castle consist of red sandstones and shales, apparently representing beds a little above the 'Yard' seam.

These red beds were originally referred by Sir R. I. Murchison and the early Northumbrian geologists to the Permian. Thus Howse in 1848 writes: 'They are the "lower-new-red-sandstones" of English geology, and from their relative position are considered equivalent to the "Rothe-todte-liegende" of Germany.' In this statement he is only following Professor Sedgwick's classification of 1826. In 1857, however, he remarks:

> At Cullercoats and Tynemouth the Red Sandstone is so evidently conformable, and passes so gradually into the shales and sandstones of the true Coal-measures, that it is impossible to separate them, or point out a line of separation,

and he goes on to state that the Red Sandstone contains at Tynemouth genuine Coal-measure fossils. In 1863, in his joint work with Kirkby, he allows the latter to sum up the question thus:

> We include the Lower Red Sandstone as Permian with some hesitation, for it will be seen that all fossils are Coal-measure species. This fact would certainly have induced us to place it in the Carboniferous system, rather than with the Permian strata, had we not been aware that several other Carboniferous species extended up into the Magnesian Limestone. We therefore with some reluctance ignore for the present the palæontological evidence, and classify this deposit as we do, on the grounds of its apparent conformability with the Magnesian Limestone.

In 1889, in his guide to the local fossils, Howse entirely abandons this view and, in speaking of these two deposits, remarks:

> It (the yellow sand) may be the English equivalent of the German *Weissliegende*, which is also an anomalous deposit, and, if so, must be admitted to be Permian, as the *Weissliegende*, in some parts of Germany, contains characteristic and well-known Magnesian Limestone or Permian species. There is no Rothliegende in these counties, the beds so classified are merely the disturbed denuded edges of the true Coal-measures.

In the last edition of his *Outlines*, Professor Lebour, referring to these beds, writes:

> Messrs. Daglish, Forster, Atkinson and others have always stated their conviction that they were merely the ordinary Coal-measure rocks stained red at and near their line of contact with the overlying Permian. This conviction increased experience and observation cause me now to share completely.

The 'smuggler's' cave in Cullercoats bay has been excavated out of these beds where they are let down against the north side of the Ninety-fathom dyke, and here, as pointed out by Professor Lebour, the rock is calcareous in spots, giving rise to a curious knobby appearance on the weathered surfaces, due to segregation of calcareous cementing matter round certain points.

The unconformity of these yellow sands upon the Coal-measures, now generally accepted, is well illustrated by the fact that at Tynemouth the Permian strata rest on the Red Sandstone not far above the 'Metal' or 'Grey' seam, while at Killingworth, only six miles away, a coal-seam known as the 'Clousden Hill' seam is found, 1,000 feet higher in the formation, showing the denudation of a great thickness of Carboniferous rocks before the deposition of the Permian beds.

Historical.—The first published account of the Permian rocks in Northumberland is apparently that by Winch in 1814, in which he maps the beds as a continuous outcrop as far as Whitley, though he alludes to the Ninety-fathom dyke at Cullercoats as dislocating the Coal-measures and passing into the sea, and remarks, 'here is the northern extremity of the west boundary of the Magnesian Limestone,' but he does not seem to have realised that the preservation of this patch of Permian was due to the downthrow on the north side of the fault, for, in describing the quarry at Whitley, he evidently considers the fault to be of pre-Permian age. Thus he says :

> A hollow space, formed like a basin or trough, is filled with the limestone. The length of this from east to west is about a mile, the breadth from north to south 400 yards, the depth seventy feet. The beds *pass over* the Ninety-fathom dyke, which has occasioned in them no confusion or dislocation ; so that there can be little hazard in stating that the beds of the Magnesian Limestone belong to a more recent formation than those of the coal-field.

He gives a detailed description of these beds, and also records the presence of strings of galena and of fossils. He also states that the stone is obtained for lime by lighting fires against the rock, thus causing it to split off. In the same year Dr. Thomson, in the *Annals of Philosophy*, traces the boundary between the Coal-measures and the Permian deposits. He alludes to the Ninety-fathom dyke as the 'Great' dyke, stating that it enters the sea a little south of Hartley. Incidentally also he first mentions the occurrence of 'flexible' limestone in the Magnesian rocks ; his examples, however, are taken from Marsden.

In 1826 Professor Adam Sedgwick published his classical paper on the Magnesian Limestone. In this work he alludes to the Permian rocks of Northumberland, and criticises Winch's statement that the Ninety-fathom dyke passes through the Whitley quarries as irreconcilable with his own observations regarding the dyke. He records the occurrence of nodules of galena and blende, and considers that the mode of occurrence of the former indicates a contemporaneous origin. The next allusion to these beds is that in 1831 by Nicholas Wood, who however merely briefly describes them. Up to this time and until some years later no allusion appears to have been made to the beautifully preserved fish remains in the marl-slate of Cullercoats bay. The first printed notice occurs in Howse' *Catalogue of Permian Fossils*, published in 1848, where he remarks :

> This bed is exceedingly interesting on account of the numerous remains of fishes which are preserved in it. They are found pressed quite flat between the laminæ of which this bed is composed, in the following localities, Whitley quarries and Cullercoats bay, etc. Last summer, while working some marl-slate in Cullercoats bay, to which our attention was directed by Mr. A. Hancock, we obtained two specimens of a *Palæoniscus*,

so that the discovery of this rich locality must evidently have been made by Albany Hancock about 1847, but an account of it was only published by him in the *Natural History Transactions* for 1849. In his *Monograph of Permian Fossils*, published in 1850, William King figures several species of invertebrata from the Whitley quarries, as for instance: *Synocladia virgulacea*, *Cyathocrinus ramosus*, *Spirifer alatus*, *Spiriferina cristata*, *Camarophoria globulina*, etc. He also figures species of fish which occur in the marl-slate of Cullercoats. In 1857 Howse published the supplement to his former catalogue, and in 1863 appeared the *Synopsis of the Geology of Durham and Part of Northumberland*, by Howse and Kirkby, a pamphlet published especially in connection with the visit of the British Association to Newcastle. In this he records most of the important points in connection with the Permian rocks in Northumberland. In the same year appeared Binney and Kirkby's translation of Geinitz' work, *The Dyas*, as far as it referred to the British Permian beds. Since this time but little has been published which is new on these beds in Northumberland. A fine collection of fish from the marl-slate at Cullercoats, collected by the late Mr. Dinning, has however been presented to the Hancock Museum.

In 1878 Professor Lebour published his *Outlines of the Geology of Northumberland*, which again summarises our knowledge of the Permian deposits of Northumberland, while a second edition of this work was issued in 1886. Lastly, in 1889, Mr. Howse completed his guide to the local fossils in the Hancock Museum, in which will be found the latest list of Northumberland fossils from the marl-slate and Magnesian Limestone of Cullercoats and Whitley.

The Coal-measures.—The beds of this formation constitute the whole of the solid geology of the district, with the exception of the small outliers of Permian rocks mentioned above, and must represent an aggregate thickness of some 1,200 to 1,400 feet. They consist of sandstones, firestones and shales, with occasional coal-seams and clay-ironstones. The latter are often rich in lamellibranch remains (*Anthracosia*, *Carbonicola*), when they constitute the well known *Mussel Bands* of the miner, and frequently contain over 18 per cent. of iron protoxide. At least three of these mussel bands occur in this portion of the coal-field at definite horizons; one a few feet above the Low Main seam, another close above the High Main, while a third is recorded from the Seaton Delaval colliery from above the 'Yard' coal. The first of these is well seen in the Whitley cliffs, in connection with the conglomerate mentioned below, while another band is visible along the coast near Hartley.

The coals in the district include most of the important seams worked in Northumberland down to the Low Main seam. The highest coal recorded is the so-called 'Clousden Hill' seam, described by Mr. Hutton on the anthority of the late Mr. N. Wood as occurring in a quarry on the north side of the Ninety-fathom dyke, just on the western limit of this district, 800 yards south of Killingworth House and 450 feet above the Monkton seam. The chief seams below this, in descending order, are the Five-quarter seam and the Three-quarter or Seventy-fathom coal, both of the Cowpen district, near Blyth; the High Main, the Grey and Blake seams of Seghill and Cramlington, the Yard Coal, the Bensham seam and the Low Main or Hutton seam. At the present day the most important seam worked is the Low Main, which occurs at a wonderfully uniform depth; thus at Bebside colliery it lies at 93 fathoms from the surface, at Low Newsham colliery at 104 fathoms, at Cramlington colliery at 72 fathoms, and at Seaton Delaval at 102 fathoms. The High Main, once the most notable seam, is now practically worked out or abandoned; it formerly supplied the famous 'Wallsend' coal of the south of the district.

The general dip of the beds, as seen on the coast between Seaton Sluice and Cullercoats, is uniformly to the south-west. North of Seaton, however, and inland, the beds are much disturbed by faults. South of the Ninety-fathom dyke, the beds, where exposed on the coast, dip due south as far as the fault occupied by the Tynemouth dyke. South of this again, near the Black Middens, the dip changes to east.

The chief faults traversing this coal-field, though irregular, run roughly east and west in the general direction of the dip of the beds. Their chief effect is therefore a lateral shifting of the outcrop, but nevertheless the dip of the beds is never great, being usually between two and ten degrees.

The Ninety-fathom dyke is however an exception to this rule, since the beds in the neighbourhood of Cullercoats are dipping south, while the fault is a 'strike' fault running due west from the coast. As a result we get all the seams from the Low Main to the High Main repeated at the surface on the south side of the fault. The Low Main thus crops out on the coast just south of Cullercoats bay, the Bensham seam runs into the sea in the middle of the Long Sands, while the 'Yard' coal is seen in the cliff midway between Sharpness Point and Tynemouth castle, and a small seam which is frequently exposed after storms beneath the Boulder-clay, west of the Black Middens, is probably the 'Grey' or 'Blake' seam. The High Main is not seen on the coast but crops out inland from Chirton Hill by the south of Murton to Backworth station, west of which it disappears against the fault.

Another important fault is the Brierdean dyke, which has a downthrow of eighty feet to the north and shifts the outcrop of the High Main coal from Earsdon to a position midway between Hartley and Brierdean farms. At Crag Point, again, farther north, we find a pair of dislocations which throw the strata down eighty-five degrees to the north, and turn the dip on the north side round to the north-west. At Seaton Sluice, on the other hand, a fault lets down the beds seventy-eight feet on the south, so that these two faults practically neutralize one another. A peculiar group of faults, radiating like a 'starred' pane of glass, occur round Cowpen colliery, all of which have a downthrow on their southern side. Lastly, in the extreme south of Tynemouth parish, a fault occurs with a downthrow of 180 feet to the south, which runs from the Narrows at the mouth of the Tyne westward to Millbank.

The sandstones vary considerably in colour and texture, but form a valuable building stone in the district; they are frequently false-bedded and show shallow water characteristics. In 1852 Dr. Sorby attempted to work out the direction from which the currents had flowed during the depositions of these sandstones between the Tyne and Seaton Sluice. From careful observation he deduced that the drift ripples in the Red Sandstone under Tynemouth castle show a mean direction from north nine degrees east, while the beds at Cullercoats show a direction north twenty degrees east. The sandstones between Hartley and Seaton Sluice, which he considers to be the same beds, showed a drift from north seven-

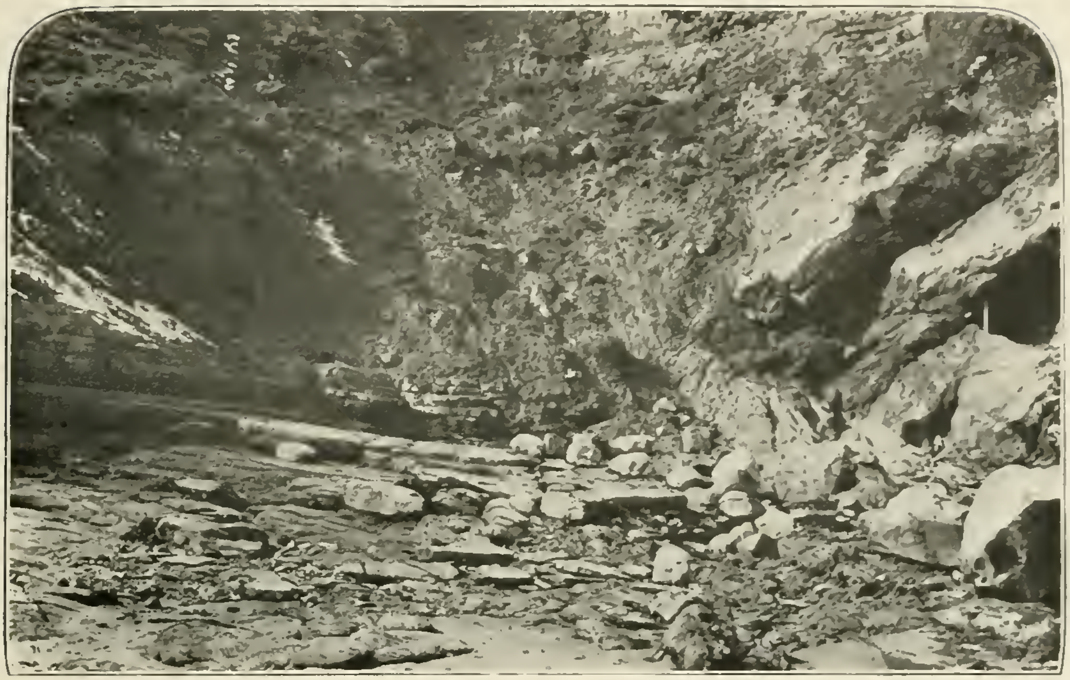

FIG. 1.—THE NINETY-FATHOM DYKE AT CULLERCOATS

(SHOWING THE COAL-MEASURES ON THE LEFT BROUGHT AGAINGST THE PERMIAN ON THE RIGHT, SEE P. 8).

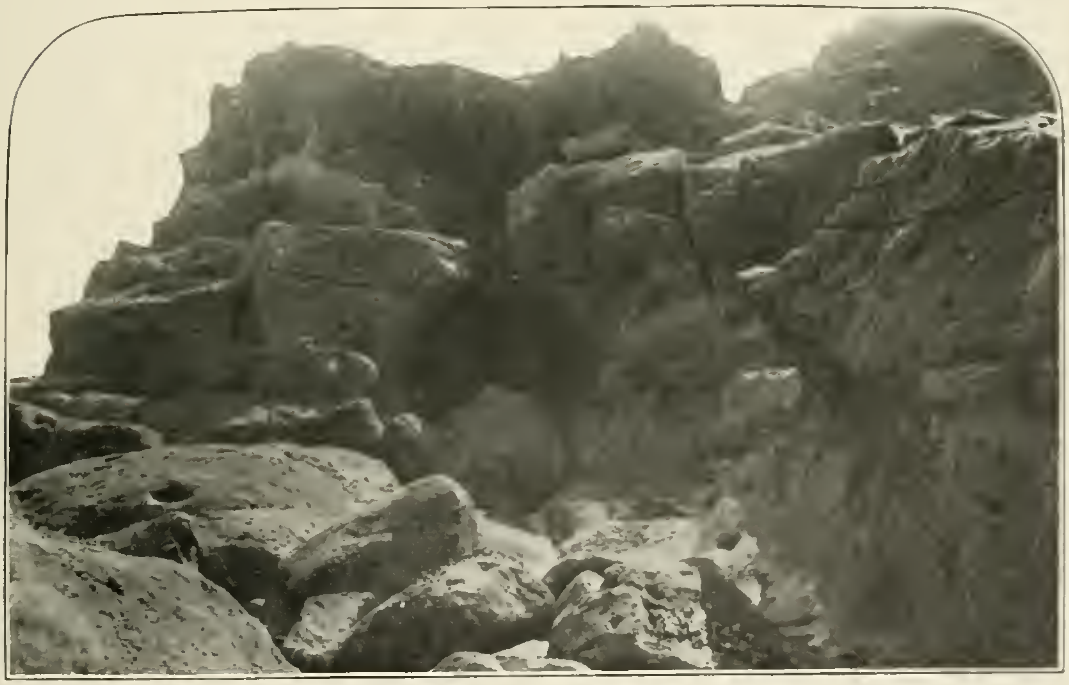

FIG. 2—TABLE ROCKS, WHITLEY

(SHOWING MARINE DENUDATION ALONG A JOINT, SEE P. 16).

teen degrees east. He thought the current must have been a very uniform one and indicated a considerable velocity. He noted great variety in individual beds of the true Coal-measures on this coast and sums up his results as follows:

> We have in the coal strata of the coast section, between Tynemouth and Seaton Sluice, beds drifted from very various quarters, but yet they may all be divided into two leading groups, namely, those which have come from some point between north-east, passing through north and west to south-west; and those from between south and east, there being none from any point between south and south-east, or east and north-east.

Among other important sandstones which crop out in this district, special mention may be made of the well-known Burradon firestone between Killingworth and Seghill. Many of these sandstones show concentric ferruginous staining, and sometimes this is concentrated into concretionary nodules. A good example occurs in the cliff immediately under Northumberland Terrace.

With regard to the shales, many of these yield plant remains, which have been especially collected from the beds associated with the High Main, Bensham, and Low Main seams. Specimens of these are displayed in the collection at Barras Bridge. They have been procured from the Low Main at Newsham, Killingworth and Cramlington, and from the Ironstone shale at Whitley, and no doubt occur in connection with other seams.

Of still greater interest are the unique collections of fish and amphibians which have been obtained in such quantities and in such a fine state of preservation from the shale associated with the Low Main seam at Newsham colliery. Over thirty papers have been written by Owen, Agassiz, Albany Hancock, Atthey, Barkas and Embleton on the remains discovered in this bed, a summary of which, by Mr. Howse, will be found in *The Industrial Resources of the Tyne*, and also in the *Guide to the Local Fossils*, published by the same author in 1889. The unique collection made by the late Mr. Atthey is exhibited in the Newcastle museum. This collection includes thirty species of fish and six species of amphibians, four of them being originally described from this locality, while of the fish the interesting species of the rays, *Janassa linguaeformis*, together with six species of the dipnoid *Ctenodus*, were first discovered by Atthey in this shale. Indeed, so rich was this shale in fish remains that at one time Mr. T. P. Barkas, who was the recipient of many of the fossils discovered in the pit, was reduced to advertising gifts of typical specimens to any readers of the *Geological Magazine* who would relieve him of his overwhelming store. Much interest was excited at one time by the alleged discovery by the same gentleman of mammalian remains from this bed. Subsequent investigation, however, failed to confirm this identification. Quite recently (1904) an interesting discovery has been made by Professor Lebour and Dr. Smythe in connection with the order of succession of the Coal-measures in this district, and the writer is indebted to these gentlemen for very kindly furnishing him with the following notes, in anticipation of a fuller description elsewhere. The discovery was made in connection with a series of shales and their beds of sandstone underlying the Table Rock sandstone in Whitley bay. These beds are only exposed at low tide, and the shore is inaccessible at other times, a fact which may account for this interesting section having escaped the attention of previous observers.

The junction between this series and the cliff-making sandstone above it is marked by a number of stratigraphical irregularities. These irregularities are rendered specially noticeable by carefully mapping the outcrop of a band of clay-ironstone crowded with *Carbonicola* (*Anthracosia*), which forms part of the lower set of deposits referred to. It is then clear that whilst the overlying sandstone is continuous and practically unbroken from its emergence above sea-level nearly as far as the Brier Dene, with a small dip inland which makes its strike coincide with the coastline, it is far otherwise with the mussel-band and its associated strata. These, though often for several yards running in apparent concordance of strike with the cliff-sandstone, over and over again become bent into folds—some gentle and others of violent pitch—most of which have their axes at right angles, or nearly so, to the strike of the sandstone. Moreover, these folds in numerous cases have given rise to small reversed faults of high (*i.e.*, flat) hade. Besides these disturbances, all in the same direction, the lower series is broken up by a few ordinary faults. Now these folds, reversed faults and nearly all the normal faults, affect the lower beds only, including the guiding mussel-band, and leave the sandstone above undisturbed. Here, therefore, are all the characters of an unconformity accompanied with occasionally great discordance of dip; and some of the characters of the floor of a thrust.

Examining now the cliff sandstone equally minutely, it is found that what change can be observed in it is chiefly this: in proceeding northwards the formation becomes less and less massive until near the northern end of the cliff-section, where a marked interlacing of shale and sandstone takes place, some of the wedging out and in of the constituent beds in one or two places showing by internal faulting that some differential movement undoubtedly took place, but only, be it noted, where the rock ceases to be essentially one massive deposit. Thus the sandstone, as well as the beds beneath, bears witness to something of the nature of thrusting, and the evidence from both points to the movement having been from south to north. But there might be thrusting without unconformity. The evidence of the denudation of the lower before the deposition of the higher beds is completed by the fact that fragments of the former are found in many places in the bottom position of the latter, and that these fragments include rolled and waterworn pebbles of the mussel-band already mentioned.

It is thus concluded (and many minor details uphold the conclusion) that the Table Rock sandstone was not deposited until the shales and other beds beneath it, including the mussel-band, had been denuded, and that after such deposition had taken place, the upper sandstone (and probably all above it) was moved a certain distance, chiefly to the north over the edges of lower beds.

The mussel-band is supposed to be the shelly layer a few fathoms above the Low Main coal, but this is by no means certain. What the exact horizon of the Table Rock sandstone may be, except that it must be high up in the Coal-measures, is by no means certain either.

It is clear that though the unconformity and accompanying thrust may not be, either of them, large in amount, yet in the absence of evidence on this point, their occurrence is well worth notice, since, should the lapse of time represented by the one and the shift due to the other be greater than is supposed, they may lead to an explanation of the difficulty which has frequently been felt in attempting to correlate some of the coal-seams in the south-east corner of Northumberland, and especially in that portion of the Durham Coal-measures which in the north-east of that county are concealed by the overlying Permian bed.

Dykes.—Five important Whin dykes reach the coast between the Tyne and Blyth. They are exactly parallel to one another, and belong to Professor Lebour's east and west series; the most southernly reaches the coast at the mouth of the Tyne, while the most northernly appears in the river Blyth, just beyond the parish boundary.

Of the three intermediate dykes, the two most southernly run about a quarter of a mile apart and reach the coast a little south of Seaton Sluice and at Crag Point respectively, while the one still farther to the north appears to run out to sea under the Blyth links, due east of Barras farm. The three southernly intrusions are connected with a set of east and west faults, but they do not, as a rule, seem to be affected by any of the cross faults associated with them, and would therefore appear to be younger than those dislocations; in fact, on account of their parallelism with similar dykes north of the Scottish border, they are usually regarded as of Tertiary age.

They are, however, far from continuous, and have a habit of dying out and overlapping along parallel fissures, especially in their westerly continuation beyond the boundary of the district. This feature is well seen, however, on the coast in the case of the Seaton dyke.

Winch evidently regarded the Seaton and Hartley dykes as one and the same, for he remarks, 'Another (dyke), about three yards wide, appears in the cliffs over Seaton Sluice: its direction is W.N.W., and it may again be seen in Hartley burn.' Wood also mentions the Hartley dyke, and alludes to its connection with a fault, and also describes the manner in which the coal in contact with it is charred where it is seen in the cliff.

This intrusion also shows, incidentally, a good example of the vertical dying-out of a dyke, as pointed out by Professor Lebour, for, near the spring on the beach, it is at least twelve feet wide at the foot of the cliff, where it is seen dying away upwards after dividing into two tongues, the longer of which thins out beneath a bed of sandstone about eleven feet below the surface, though the fault, along which it was intruded, is still seen continuing upwards.

The same feature is reported by Dr. Teall from another section inland where the dyke was exposed in a small quarry on the east side of the dene. Here the dyke was seen to diminish five feet in width in a height of about twenty feet, being about ten feet wide at the bottom and five feet at the top of the quarry, where it terminates abruptly upwards, arching up the shales above it. The Hartley dyke has been met with in the Shankhouse pit to the west where it was seen to be seven or eight feet wide and contained a fault breccia in the centre. The northern exposure in this colliery showed an example of the duplicating and overlapping mentioned above, one intrusion measuring several feet and the other only eleven inches in thickness. As usual the coal here was charred and altered into 'white whin.' The rock is very uniform in different exposures and resembles very closely the Tynemouth and Brunton dykes.

The Tynemouth dyke shows features of particular interest. It was first briefly described by Winch in 1814, in his paper read before the Geological Society, as follows:

> A basaltic dyke six feet wide may be seen among the rocks of the coal formation at the south-eastern corner of the promontory on which Tynemouth castle stands.

This is his description on page 24 of the above work; he does not, however, seem to have visited it himself, for before concluding his paper he appears to have forgotten this description and he proceeds to redescribe it as follows:

> The next basaltic dyke worthy of notice is one which, passing from west to east under Tynemouth priory, may be seen to divide the strata at the south-east point of Prior's Haven, where it forms a wall twelve feet broad in the cliff, and in the rocks below a vein or fissure twelve inches in breadth and filled with tufaceous matter intersects the dyke from top to bottom near its centre, and the basalt strongly resembles the Coley-hill stone.

In 1826 Professor Sedgwick, in discussing the date of intrusion of the north of England basaltic dykes, remarks:

> The Trap dyke at the south-west end of Tynemouth castle cliff is unfortunately of no assistance to this enquiry, because the capping of yellow limestone does not extend to that extremity of the cliff where the dyke is present. Such is the imperfect evidence, or rather such is the absence of all direct evidence, in favour of the conclusion, that the Trap dykes in our northern coal-fields belong to an age which is anterior to the deposition of the Magnesian Limestone.

The next mention we find of this dyke is by Nicholas Wood in 1831. In describing the beds at Tynemouth he remarks, 'a whin dyke, shown in section, from twelve to fourteen feet in width, and differing in no respect from those generally found in this district, here intersects the Yellow Sandstone and Red Sandstone, at right angles to the stratification of the beds; but it cannot, from the incumbent alluvial matter, be ascertained if it also pierces the Magnesian Limestone.'

At the present day this dyke is still exposed in the south-west corner of Prior's Haven, just at the angle where the flight of steps descends from the north pier to the shore. The exposure shows a width of about ten feet and contains a brecciated quartz vein, six inches wide, near the middle. This is no doubt the vein, 'twelve inches wide, filled with tufaceous matter,' described by Winch. This central vein is very characteristic of many whin dykes; it is noticeably present in the inland exposures of the Hartley dyke, and is no doubt a feature resulting from the lateral cooling and shrinkage of the basalt, leaving a plane of weakness in the centre, along which movement or infiltration has taken place, as suggested by Dr. Teall.

The dyke was also exposed in 1882 in the excavations for the new railway station. Dr. Teall, who examined this exposure, writes:

> The most interesting feature connected with this exposure was the evidence of a breach in the continuity of the dyke, accompanied by a lateral shift in the outcrop, amounting to seventeen yards. The width of the dyke was about eleven or twelve feet, and it possessed a hade to the north. Farther west the same dyke has been met with near Billy Mill by Mr. Flavell, during the construction of works by the North Shields Water Company. Still farther to the west, near Newcastle, occurs the well-known Coley-hill dyke, which was formerly worked on a very extensive scale for road-metal, and the course of which is now indicated by a deep trench.

This dyke agrees in general direction with the Tynemouth dyke; Winch appears to have regarded the two as connected, and Dr. Teall comes to the same conclusion from a microscopic examination of the two rocks. In appearance the Tynemouth dyke is a dark compact rock, containing crystalline aggregates of anorthite felspar embedded in a dark, finely crystalline ground-mass composed of augite, lath-shaped felspars and interstitial matter. Olivine is occasionally present, forming a rock to which Rosenbusch has given the name of trolleite. The rock often exhibits small white spots scattered irregularly through it. These are due partly to the presence of amygdules and partly to the porphyritic crystals of anorthite felspar. Dr. Teall, who has described the rock in detail, points out the interest of these spots. The porphyritic felspars are crystalline aggregates in which the outer zone of felspar substance possesses optical properties different from the central portion. The spherical amygdaloids vary in size from that of a mustard seed to that of a peppercorn, and as a general rule vary in quantity inversely with the anorthite aggregates. They consist of calcite and frequently contain a chalcedony border. One point of interest is the manner in which, during the formation of the bubble, the lath-shaped felspars have been pushed aside and arranged tangentially to the vesicles, while the interstitial matter is in no wise affected, being of later consolidation. These vesicles have been compared by Dr. Teall to the bubbles which rise in the contents of a soda water bottle as the cork is partially removed. In some cases the vesicles are filled partly or entirely with interstitial matter, which evidently entered on the escape or condensation of the gas. On the whole, the rock agrees microscopically as well as macroscopically with the Coley-hill dyke.

The dyke is intruded in the Coal-measures. The Permian strata are not seen in contact with it at the present day. Nicholas Wood's statement that in 1831 it could be seen intersecting the yellow sand is therefore of interest, but if the absence of the Permian beds above the dyke at the present day is due to subsequent denudations, it is curious that Sedgwick, writing in 1826, five years before Wood, should expressly regret that the dyke could not be seen in contact with the Permian strata. It is true that Sedgwick uses the expression 'yellow limestone,' but he specially insists on the inclusion of the lower sands in the Permian formation, and also states that the same sandstone is twenty-five feet thick under Tynemouth priory. It is obvious then that no such penetration of the yellow sands by the dyke was visible in 1826. The above statement by Winch, in 1814, that the dyke penetrated the coal formation, without any allusion to the Permian strata, is also against Wood's statement. An examination therefore of such records as we possess leaves the date of intrusion of the dykes, as testified by this critical example, still an open question. There is, however, evidence of a different character which seems to bear on this question. The east and west faults traversing the rocks in this neighbourhood appear to affect the Permian rocks as well as the Coal-measures, though this is by no means universally the case in Durham. This is notably seen in the case of the Ninety-fathom dyke and also several minor faults which are visible in the Tynemouth castle cliff; one of these is even figured by Sedgwick. The Tynemouth dyke occurs along one of these faults, which has a downthrow of fourteen feet to the north. It is obvious that the presence of this fault has directly influenced the intrusion of the basalt along this line, and that the dyke is posterior to the formation of the fault. There is therefore strong indirect evidence that the date of intrusion of the Tynemouth dyke is post-Permian.

Glacial Deposits.—The deposits of this age are, on the whole, similar to those described in previous volumes of this history. The section, however, exposed between the Lifeboat station and the Low Lights, exhibits some points of special interest. The Boulder-clay here occupies the whole of the cliff, constantly giving rise to landslips. The clay is mostly unstratified and full of boulders of local rocks, together with Cheviot andesites and Scottish granites. No undoubted examples of Norwegian rocks have been found, but, at the top of the cliff, fragments of sharp flint and rounded pebbles of clear quartz occur in considerable abundance. Writing of this deposit, Mr. Howse remarks: 'It is at present uncertain whether this bed is a reconstruction of the Boulder-clay or a prolongation on to this coast of the Scandinavian drift. The flints seem to bear a very striking resemblance to some collected in the latter formation near Hamburg.' Though this was written in 1863, no definite solution of the problem has yet been arrived at. It is difficult to see how any 'reconstruction' of the Boulder-clay could produce true flints. We know of no Upper Cretaceous rocks cropping out in Northumberland from which they could have been derived, and they do not occur in the Boulder-clay farther north. Some of the layers near the upper part of this deposit also contain lenticular patches of sand which have very much the appearance of frozen fragments of the sea-bottom brought up to their present position by the shearing action of ice. This suggestion seems to be confirmed by the presence of marine shells, found in the sands by Mr. Howse.

An elevated beach, composed of fragments of Magnesian Limestone chiefly, with remains of flints and also pebbles from the Boulder-clay interstratified with beds of sand and grit and a very fine glacial silt, occurs in a section lately made in the castle-yard at Tynemouth. It contains also the remains of a marine shell, *Cyprina Islandica*, some fragments of which have been also detected in the Boulder-clay. This beach deposit rests on a thin bed of clay with pebbles, which appears to be a reconstruction of the Boulder-clay, under which is the proper rock surface. It reposes on a slope to the west, and contains material derived from some Magnesian Limestone cliff—from a cliff, in fact, which must have been situated considerably east of the present line of coast. The invasion of the sea from the west is only what we might expect when we remember the presence of undoubted Scandinavian erratics along our east coast, from the orthite-bearing 'Savil' boulder of Sanda Island to the blocks of 'rhombic' porphyry on the Cromer coast.

Another very interesting feature was exposed at the base of this section a few years ago, but is no longer visible in 1904. It occurred a little beyond the last outcrop of sandstone of the Black Middens, which disappears under the beach, going westwards. Here the lower part of the Boulder-clay was seen to enclose layers of the sandstone broken up and folded into arches and troughs, and dragged out over the lowest layers of the Boulder-clay to the west, showing that the surface of the sandstone had been torn off by some solid object, travelling from east to west, and dragged over a bed of Boulder-clay previously deposited. The fragments, though disconnected, nevertheless still maintained their relative positions.[1] This fact, taken together with the manner in which it was folded, showed plainly that it must have been the work of ice. This proof of motion from east to west appears to afford additional evidence that the Northumberland ice was not free to move eastward, but was blocked and directed westward by some obstruction in the North Sea ; it is difficult to see what other obstruction this could be but foreign ice from the north-east.

It is impossible to conclude this brief notice of the geology of a very interesting district without a word regarding the present disintegration of the coast line. This is naturally taking place most rapidly along the portion of the coast formed of Boulder-clay. Thus a massive stone wall, built by the then duke of Northumberland in 1811, supported the banks below Percy Square. The lime resisted disintegration longer than the stone, and stood out in sharp ridges. After the destruction of this wall and its outlying timber groyne, the cliff became undermined and landslips began to take place in the Boulder-clay. The front row of cottages in Percy Square disappeared, and up to 1892 about a hundred feet of frontage west of the front cottages had disappeared, while in 1827 the cliff is stated to have extended eighty feet farther seaward. Again, between Percy Square and the Howling, four acres have disappeared. Mr. Robert Tate estimated that 556,600 tons had fallen into the Tyne estuary in sixty-five years. The coast line is therefore here wasting at the rate of 8,560 tons a year. In other portions of the coast the sandstones and shales are being denuded at a considerable rate. One of the best examples of the method by which the sea obtains access into the heart of the sandstone is seen at the Table Rocks. Here a joint running nearly parallel to the coast-line has been enlarged by the seas coming from the north-east, a long water-worn tunnel penetrates the rock, and large rounded blocks can be seen at low tide lying in the trench, while farther inland the joint can be traced along which the destruction is taking place.

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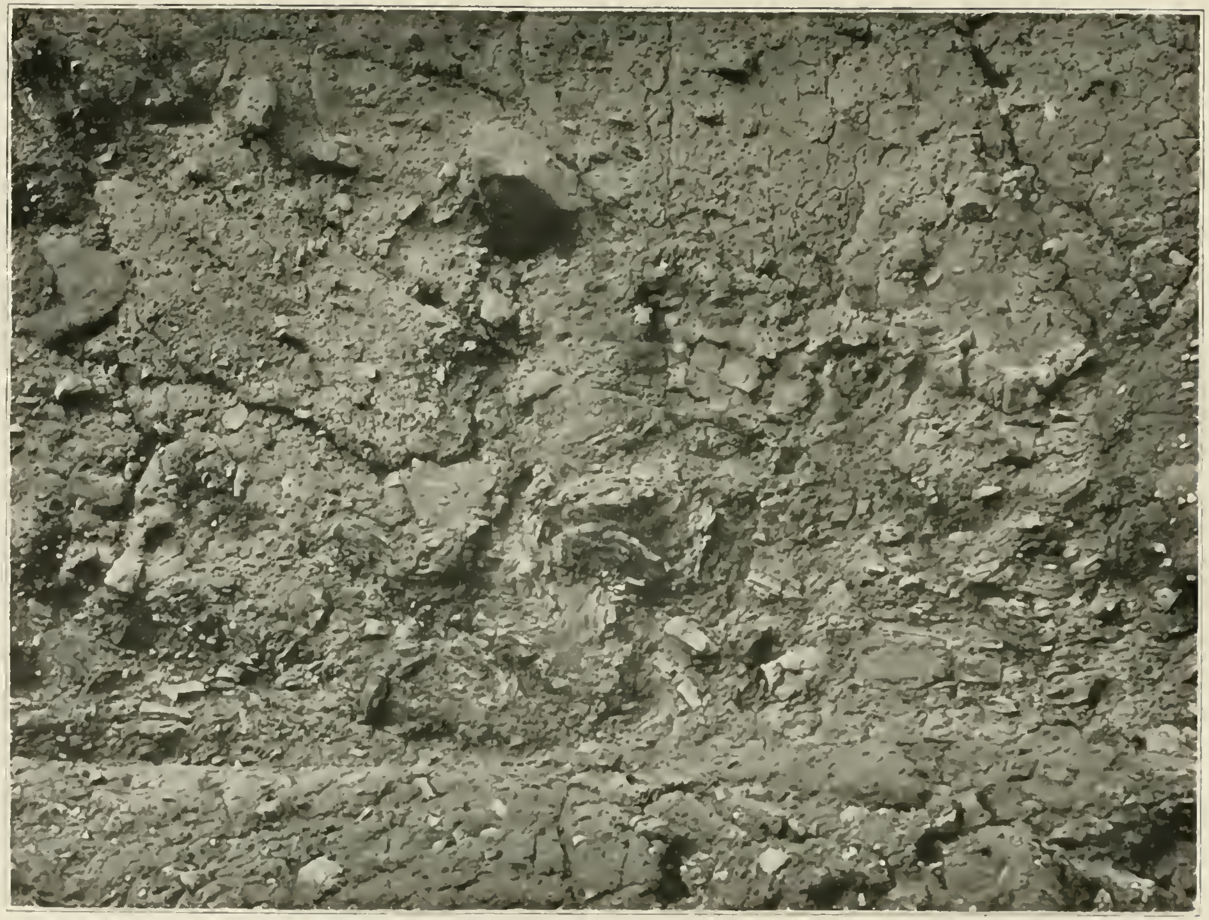
[1] See Plate II.

PLATE II.



View of Boulder-clay